532 Rec'd PCT/PTO 12 SEP 2000

FORM PTO-1390 (REV. 5-93)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
		10191/1577

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
09/623342

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE98/03741	(21.12.98) 21 December 1998	(05.03.98) 05 March 1998

TITLE OF INVENTION
SCHALTREGLER (**SWITCH CONTROLLER**)

APPLICANT(S) FOR DO/EO/US:
OHMS, Franz

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, PCT/RO/101, Return Receipt Postcard.

EXPRESS NO.:EL594606890US

534 Rec'd PCT/PTO 31 AUG 2000

U.S. APPLICATION NO. if known, see 37 C.F.R.1.5 09/623342	INTERNATIONAL APPLICATION NO. PCT/DE98/03741	ATTORNEY'S DOCKET NUMBER 10191/1577	
17. ☒ The following fees are submitted:		CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $840.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $670.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $760.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $970.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $96.00			
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 840.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	9 - 20 =	0	X $18.00	$	
Independent Claims	1 - 3 =	0	X $78.00	$	
Multiple dependent claim(s) (if applicable)			+ $260.00	$	

TOTAL OF ABOVE CALCULATIONS =	$ 840.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).	$	
SUBTOTAL =	$ 840.00	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 840.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 840.00	
	Amount to be: refunded	$
	charged	$

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of $840.00 duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

By: [signature] Reg No 35,952

[signature]
SIGNATURE

Kenyon & Kenyon
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Richard L. Mayer
NAME

22,490
REGISTRATION NUMBER

8/31/00
DATE

309524-1

13 Rec'd PCT/PTO 22 MAR 2001
09/623342

[10191/1577]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Franz OHMS
Serial No.	:	09/623,342
Filed	:	August 31, 2000
For	:	SWITCHING CONTROLLER
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (and Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

On page 8, change "Patent Claims" to --WHAT IS CLAIMED IS:--

Please cancel, without prejudice, claims 1-9 in the underlying PCT application.

Please also cancel, without prejudice, claims 1-8 in the annex to the International Preliminary Examination Report.

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Please add the following new claims:

10. (New) A switching controller, comprising:

a final controlling element;

a pulse-duration or pulse-frequency modulator coupled to the final controlling element, the pulse-duration or pulse-frequency modulator controlling the final controlling element;

an error signal amplifier coupled to the pulse-duration or pulse-frequency modulator, the error signal amplifier exhibiting P action and acting on the pulse-duration or pulse-frequency modulator;

an evaluation circuit to detect a load performance of the switching controller, the evaluation circuit configured to detect only an alternating component of a load-step dependent signal of the switching controller, a time constant of the evaluation circuit being set so that the error signal amplifier compensates for a decaying control deviation of the signal detected by the evaluation circuit, the signal detected by the evaluation circuit being provided as a pre-control signal for the pulse-duration or pulse-frequency modulator; and

a coupling device for the signal detected by the evaluation circuit, the coupling device provided between an output of the error signal amplifier and an input of the pulse-duration or pulse-frequency modulator.

11. (New) The switching controller according to claim 10, wherein the coupling device includes an adding circuit or node, an output signal from the error signal amplifier being gated with the signal detected by the evaluation circuit.

12. (New) The switching controller according to claim 10, wherein an amplitude of an output signal of the error signal amplifier is modified in comparison with a switching controller without a coupling device to a degree corresponding to a load-step-dependent value detected by the evaluation circuit.

13. (New) The switching controller according to claim 10, wherein the signal detected by the evaluation circuit is an alternating component of a load current of the switching component.

14. (New) The switching controller according to claim 11, wherein the signal detected by the evaluation circuit and an output signal of the error signal amplifier are routed to the adding circuit or node via resistors of equal value.

15. (New) The switching controller according to claim 10, wherein the evaluation circuit includes a measuring current transformer and a downstream amplifier, the downstream amplifier being downstream from the measuring current transformer.

16. (New) The switching controller according to claim 10, wherein the pulse-duration or pulse-frequency modulator is fed an output signal from the error signal amplifier together with a superimposed output signal of the evaluation circuit, on the one hand, and a combination of at least two of the following signals, on the other hand:

a saw-tooth signal of constant amplitude,

a signal proportional to current conducted through the final controlling element,

a saw-tooth signal having a peak amplitude in proportion to an integrated input voltage of the switching controller, and

a d.c. voltage signal in proportion to a level of an input voltage of the switching controller.

17. (New) The switching controller according to claim 10, wherein a collector current of a traveling-wave tube is detected via the evaluation circuit.

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1-9 in the underlying PCT application PCT/DE98/03741. This Preliminary Amendment further cancels, without prejudice, claims 1-8 in the annex to the International Preliminary Examination Report, and adds new claims 10-17. The new claims, inter alia, conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

The above amendments to the title, the specification and the abstract conform the title, the specification and the abstract to U.S. Patent and Trademark Office rules, and do not introduce new matter into the application.

The underlying PCT application PCT/DE98/03741 includes an International Search Report, dated May 27, 1999. An English translation of the Search Report is provided herewith.

The underlying PCT application also includes an International Preliminary Examination Report ("IPER"), dated August 22, 2000. An English translation of the IPER and the annex thereto is included herewith.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

Dated: 3/22/01

By: [signature]
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[10191/1577]

SWITCHING CONTROLLER

FIELD OF THE INVENTION

The present invention relates to a switching controller in whose control loop an error signal amplifier is provided, which exhibits P (proportional) action and which acts on a pulse duration modulator or frequency modulator for the final controlling element of the switching controller.

BACKGROUND INFORMATION

A controller of the above-mentioned type is described in European Patent No. 0 355 333.

PCT Application WO 97/34363 describes a switching controller which, besides the conventional control loop for the error signal at the output of the switching controller, has an additional control loop with which a correction quantity, which is a function of the load variation, is computed. This correction quantity is additively superimposed on the error signal in order to reduce voltage fluctuations given pulse-shaped load variations at the output of the switching controller.

U.S. Patent No. 4,885,674 describes a similar switching controller having two such control loops.

In the switching controller described in European Patent No. 0 355 333, noise signals on the input voltage are optimally suppressed in their effect on the output voltage of the switching controller without the control rate being adversely affected, for instance given sudden load variations. In order to prevent large voltage dips given sudden load variations at the output, for instance in the TDMA operation of a traveling-wave amplifier in a satellite, the voltage control loop must be properly dimensionally

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designed (high P component in the error signal amplifier). This can only be done when accompanied by a large enough output capacity, if the aim is for no stability problems to occur.

SUMMARY

In accordance with the present invention, it is possible to dimensionally design the control loop to have a low P component. The output capacities of the switching controller can be reduced without causing control stability problems. This leads to a smaller type of construction for switching controllers in high-voltage parts, where substantial outlay is required for smoothing capacitors.

In accordance with the present invention, the control loop can be dimensionally designed to have a low P-component using so-called forward (unidirectional) control; circumventing the error signal amplifier. The step change in load is directly detected and delivered to the pulse-duration or pulse-frequency modulator, without the actual control loop having to respond. As a result of this precontrol, fewer automatic control delays follow step changes in load, without giving rise to stability problems.

When only the alternating component of the load current is detected for the precontrol, the precontrol decays with a time constant that can be selected such that the error signal amplifier can easily compensate for the decaying precontrol.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a basic circuit diagram of a switching controller in accordance with the present invention.

Figure 2 shows an evaluator for detecting a step change in load.

Figure 3 shows the detection of the collector current of a traveling-wave amplifier.

DETAILED DESCRIPTION

The switching controller illustrated in Figure 1 is designed as a step-down controller. It has an input d.c. voltage source Q_E, including a terminal voltage U_E. Disposed between the positive pole of the input d.c. voltage source Q_E and the positive pole of the switching controller output having output voltage U_A is the series circuit of the switching controller's final controlling element S1 in the form of a switching transistor and inductor L of the switching controller. The freewheeling diode of the switching controller is denoted by DF, and the output-side smoothing capacitor by CG. Output voltage U_A is fed to an error signal amplifier KO, which compares it to a reference voltage Ur1. If output voltage U_A exceeds reference d.c. voltage Ur1, a control signal is transmitted to pulse-duration modulator PBM (non-inverting input), whose output signal determines the pulse duty factor (ON duration relative to OFF duration) of final controlling element S1. Connected to the inverting input of pulsewidth modulator PBM and of the common ground, is the series circuit composed of a resistor R1 and two signal sources Q_{SV}, Q_{SK}, which supply saw-tooth signals U_{SV} and U_{SK}. A voltage that is proportional to the input current of the switching controller drops across resistor R1. This is achieved in that resistor R1 is traversed by the flow of the rectified secondary current of a current transformer SMW, whose primary winding is located at the input circuit of the switching controller between input d.c. voltage source Q_E and final controlling element S1. The signal source Q_{SK} carries a saw-tooth voltage:

$$U_{SK(t)} = \hat{U}_{SK}\ t/T$$

t indicating the time, T the period duration of the saw-tooth repetition frequency, and $\hat{U}_{SK}$ the maximum amplitude of the saw-tooth voltage. The maximum amplitude $\hat{U}_{SK}$ of the saw-tooth voltage is kept constant. RM designates the resistance value of resistor R1 for detecting the current through the

final controlling element; i.e., in the case of current detection by a current transformer as in Figure 1, the resistance value multiplied by the reciprocal (inverse) value of the transformation ratio of current transformer SMW. Then, RM $=\frac{R1}{ü1}$ applies, ü designating the transformation ratio of current transformer SMW. Thus, to be able to maintain the stability conditions, a certain minimum saw-tooth amplitude is required, which cannot be provided solely by the control as a function of output voltage U_A. One can modify the action of the current control amplitude by modulating the saw-tooth amplitude by way of the input voltage. For this, an additional signal source Q_{SV} is provided, which carries a saw-tooth voltage

$$U_{sv(t)} = \frac{1}{RC} \int_0^1 U_{E(t)} dt$$

Thus, this saw-tooth voltage $U_{SV}(t)$ is proportional to integrated input voltage $U_E(t)$. The time dependency of input voltage U_E of the switching controller is substantially the result of superimposed alternating components, such as a 100 Hz ripple voltage in the case of a switched-mode power supply. This noise is optimally suppressed when the arithmetic mean of current I_0 through inductor L is constant. To optimally suppress fluctuations in input voltage and satisfy the stability requirement, the conditions discussed in detail in European Patent No. 0 355 333 are met.

The present invention provides for the load step performance of the switching controller to be detected, in particular, the alternating component of load current I_L, to be suitably amplified, and fed via a coupling device E between error signal amplifier KO, exhibiting P action, to pulse-duration modulator PBM, via an evaluation circuit A, which, in the present exemplifying embodiment, is arranged between

output-side smoothing capacitor CG and an output terminal of the switching controller. The supplying of the load-step-dependent signal directly to the input of pulsewidth modulator PBM does not alter the stability of the controller, particularly with respect to phase margin and gain margin. As shown in Figure 1, coupling device E can be composed of a simple adding node or of an adding circuit, where the output signal from error signal amplifier KO is gated with the signal detected by evaluation circuit A. The two gated signals may then be fed to the adding node via resistors RF1 and RF2 of equal value.

As Figure 2 shows, the alternating component of load current I_L is expediently detected by evaluation circuit A via a measuring current transformer SW and an amplifier V that is connected in series therewith. If there is no change in the load current, i.e., no change in current I_L (e.g., given a step change in load), then there is no signal at resistor RF1. As is evident from Figure 1, given resistors RF1 and RF2 of equal value, the output signal from error signal amplifier KO is effectuated at pulse duration modulator PBM with the half-amplitude ½ U_{KO}. If the controller gain is now increased by a factor of two, it can be seen that the additional precontrol does not influence the normal control loop via the signal that is detected by the evaluation circuit A; i.e., the controller stability is not changed. If the load then changes, namely if there is a modulation of the load current, then pulse duration modulator PBM is appropriately precontrolled without the actual control loop having to respond.

Since, for example only the alternating component of load current I_L is detected, the precontrol decays with time constant TAU = LH/RS, LH representing the primary inductance of measuring current transformer SW, and RS representing the cross resistance shown in Figure 2. Specifically, a great enough time constant TAU is selected to allow error signal

amplifier KO to easily compensate for the decaying controller deviation of the precontrol.

Instead of a pulse duration modulator, a pulse frequency modulator can also be provided for the switching controller. Furthermore, the present invention can be used for any type of switching controller, such as an step-up controller, a flow transducer, an isolating transformer, etc. The present invention is particularly suitable for high-voltage parts for traveling-wave amplifiers in ground stations or satellites, where the smoothing or filtering outlay must be minimized. In these cases, the detected load current is, in particular, the collector current of the traveling-wave tube, which is transformed into the low-voltage side of the switching controller using measuring current transformer SW.

Depending on the type of switching controller and the disturbing influences, e.g. input voltage fluctuations, etc., the signals at the second input of the pulsewidth/frequency modulator that are needed for optimal controller stability are different.

In the switching controller represented in Figure 3 of European Patent No. 0 355 333, these are:
-- a saw-tooth signal Q_{SK} of constant amplitude;
-- a signal RMI_L that is proportional to the current that is conducted through final controlling element S1; and
-- a saw-tooth signal Q_{SV}, whose peak amplitude is selected in proportion to the integrated input voltage of the switching controller.

In the example embodiment shown in Figure 2 of EP 0 355 333, a d.c. voltage signal U_W is also included, which is selected in proportion to the level of the input voltage of the switching controller.

According to the present invention, it is possible to obtain

a signal that is dependent upon the step change in load using a quantity other than the load current, for instance by detecting voltage jumps in the power circuit of the switching controller. These quantities can be suitably processed and fed as precontrol signals to the pulse-duration modulator or frequency modulator.

In the example embodiment represented in Figure 3 of the present invention, the alternating component of the collector current of a traveling-wave amplifier is detected. The switching controller is used here as precontroller for a push-pull transformer GW. A high-voltage transformer HT that delivers the supply voltages for traveling-wave tube WF via high-voltage rectifier circuit HG is located in the output circuit of push-pull transformer GW. The primary winding of measuring current transformer SW1 of evaluation circuit A for evaluating collector current IC is located in the collector feed line to collector K of traveling-wave tube WF. The secondary coil is connected as shown in Figure 2. The output of evaluation circuit A leads via resistor RF1 to coupling device E, as shown in Figure 1. In traveling-wave tubes having two collectors, it usually suffices to evaluate one collector current as shown in Figure 3, particularly the current of the collector that is situated in the immediate vicinity of the Wehnelt cylinder.

Abstract of the Disclosure

In a switching controller whose error signal amplifier essentially exhibits P action, the load step performance of the switching controller is detected via an evaluation circuit. This signal is fed directly to the pulse- duration or pulse-frequency modulator for the final controlling element, substantially circumventing the error signal amplifier for the switching controller. Through this measure, output capacities of the switching controller can be reduced without stability problems.

[10191/1577]

SWITCHING CONTROLLER

[Background of the Invention] FIELD OF THE INVENTION

The present invention relates to a switching controller in whose control loop an error signal amplifier is provided, which [essentially] exhibits P (proportional) action and which acts on a pulse duration modulator or frequency modulator for the final controlling element of the switching controller. [This type of switching controller is known from European Patent 0 355 333 B1.]

BACKGROUND INFORMATION

A controller of the above-mentioned type is described in European Patent No. 0 355 333.

PCT Application WO 97/34363 describes a switching controller which, besides the conventional control loop for the error signal at the output of the switching controller, has an additional control loop with which a correction quantity, which is a function of the load variation, is computed. This correction quantity is additively superimposed on the error signal in order to reduce voltage fluctuations given pulse-shaped load variations at the output of the switching controller.

U.S. Patent No. 4,885,674 describes a similar switching controller having two such control loops.

In the switching controller described in European Patent No. 0 355 333 [B1], noise signals on the input voltage are optimally suppressed in their effect on the output voltage of the switching controller without the control rate being adversely affected, for instance given sudden load variations. In order to prevent large voltage dips given sudden load variations at the output, for instance in the

TDMA operation of a traveling-wave amplifier in a satellite, the voltage control loop must be properly dimensionally designed (high P component in the error signal amplifier). This can only be done when accompanied by a large enough output capacity, if the aim is for no stability problems to occur.

[Advantages of the Present Invention] SUMMARY

[By applying the measures in] In accordance with the [features of Claim 1] present invention, it is possible to dimensionally design the control loop to have a low P component. The output capacities of the switching controller can be reduced without causing control stability problems. This leads to a smaller type of construction for switching controllers in high-voltage parts, where substantial outlay is required for smoothing capacitors.

[The] In accordance with the present invention [is based on the realization that, through a so-called forward (uni-directional) control], the control loop can be dimensionally designed to have a low P-component [; i.e., essentially] using so-called forward (unidirectional) control; circumventing the error signal amplifier[, the]. The step change in load is directly detected and delivered to the pulse-duration or pulse-frequency modulator, without the actual control loop having to respond. As a result of this precontrol, fewer automatic control delays follow step changes in load, without giving rise to stability problems.

When only the alternating component of the load current is detected for the precontrol, the precontrol decays with a time constant that can be selected such that the error signal amplifier can easily compensate for the decaying precontrol.

[Drawings] BRIEF DESCRIPTION OF THE DRAWINGS

[Exemplifying embodiments of the present invention are

elucidated detailed with reference to the drawing, whose figures show:

Figure 1:] Figure 1 shows a basic circuit diagram of a switching controller in accordance with the present invention[;].
Figure 2 [:] shows an evaluator for detecting a step change in load[;].
Figure 3 [:] shows the detection of the collector current of a traveling-wave amplifier.

[Description of Exemplary Embodiments] DETAILED DESCRIPTION

The switching controller illustrated in Figure 1 is designed as a [buck (step-down)] step-down controller. It has an input d.c. voltage source Q_E, including a terminal voltage U_E. Disposed between the positive pole of the input d.c. voltage source Q_E and the positive pole of the switching controller output having output voltage U_A is the series circuit of the switching controller's final controlling element S1 in the form of a switching transistor and inductor L of the switching controller. The freewheeling diode of the switching controller is denoted by DF, and the output-side smoothing capacitor by CG. Output voltage U_A is fed to an error signal amplifier KO, which compares it to a reference voltage Url. If output voltage U_A exceeds reference d.c. voltage Url, a control signal is transmitted to pulse-duration modulator PBM (non-inverting input), whose output signal determines the pulse duty factor (ON duration relative to OFF duration) of final controlling element S1. Connected to the inverting input of pulsewidth modulator PBM and of the common ground, is the series circuit composed of a resistor R1 and two signal sources Q_{SV}, Q_{SK}, which supply saw-tooth signals U_{SV} and U_{SK}. A voltage that is proportional to the input current of the switching controller drops across resistor R1. This is achieved in that resistor R1 is traversed by the flow of the rectified secondary current of

a current transformer SMW, whose primary winding is located at the input circuit of the switching controller between input d.c. voltage source Q_E and final controlling element S1. The signal source Q_{SK} carries a saw-tooth voltage:

$$U_{SK(t)} = \hat{U}_{SK} \ t/T$$

t indicating the time, T the period duration of the saw-tooth repetition frequency, and $\hat{U}_{SK}$ the maximum amplitude of the saw-tooth voltage. The maximum amplitude $\hat{U}_{SK}$ of the saw-tooth voltage is kept constant. RM designates the resistance value of resistor R1 for detecting the current through the final controlling element; [i.e.] i.e., in the case of current detection by a current transformer as in Figure 1, the resistance value multiplied by the reciprocal [[inverse]] (inverse) value of the transformation ratio of current transformer SMW. Then, $RM = \frac{R1}{\ddot{u}1}$ applies, ü designating the transformation ratio of current transformer SMW. Thus, to be able to maintain the stability conditions, a certain minimum saw-tooth amplitude is required, which cannot be provided solely by the control as a function of output voltage U_A. One can modify the action of the current control amplitude by modulating the saw-tooth amplitude by way of the input voltage. For this, an additional signal source Q_{SV} is provided, which carries a saw-tooth voltage

$$U_{sv(t)} = \frac{1}{RC} \int_0^1 U_{E(t)} dt$$

Thus, this saw-tooth voltage $U_{SV}(t)$ is proportional to integrated input voltage $U_E(t)$. The time dependency of input voltage U_E of the switching controller is substantially the result of superimposed alternating components, such as a 100 Hz ripple voltage in the case of a switched-mode power supply. This noise is optimally suppressed when the arithmetic mean of current I_0 through inductor L is

constant. To optimally suppress fluctuations in input voltage and satisfy the stability requirement, the conditions discussed in detail in European Patent No. 0 355 333 [B1 must be] are met.

[At this point, the] The present invention provides for the load step performance of the switching controller to be detected, in particular, the alternating component of load current I_L, to be suitably amplified, and fed via a coupling device E between error signal amplifier KO, [essentially] exhibiting P action, to pulse-duration modulator PBM, via an evaluation circuit A, which, in the present exemplifying embodiment, is arranged between output-side smoothing capacitor CG and an output terminal of the switching controller. The supplying of the load-step-dependent signal directly to the input of pulsewidth modulator PBM does not alter the stability of the controller, particularly with respect to phase margin and gain margin. As shown in Figure 1, coupling device E can be composed of a simple adding node or of an adding circuit, where the output signal from error signal amplifier KO is gated with the signal detected by evaluation circuit A. The two gated signals [are preferably] may then be fed to the adding node via resistors RF1 and RF2 of equal value.

As Figure 2 shows, the alternating component of load current I_L is expediently detected by evaluation circuit A via a measuring current transformer SW and an amplifier V that is connected in series therewith. If there is no change in the load current, [i.e.] i.e, no change in current I_L (e.g., given a step change in load), then there is no signal at resistor RF1. As is evident from Figure 1, given resistors RF1 and RF2 of equal value, the output signal from error signal amplifier KO is effectuated at pulse duration modulator PBM with the half-amplitude ½ U_{KO}. If the controller gain is now increased by a factor of two, it can be seen that the additional precontrol does not influence

the normal control loop via the signal that is detected by the evaluation circuit A; [i.e.] i.e, the controller stability is not changed. If the load then changes, namely if there is a modulation of the load current, then pulse duration modulator PBM is appropriately precontrolled without the actual control loop having to respond.

Since [preferably], for example only the alternating component of load current I_L is detected, the precontrol decays with time constant TAU = LH/RS, LH representing the primary inductance of measuring current transformer SW, and RS representing the cross resistance shown in Figure 2. Specifically, a great enough time constant TAU is selected to allow error signal amplifier KO to easily compensate for the decaying controller deviation of the precontrol.

Instead of a pulse duration modulator, a pulse frequency modulator can also be provided for the switching controller. Furthermore, the present invention can be used for any type of switching controller, such as an step-up controller, a flow transducer, an isolating transformer, etc. The present invention is particularly suitable for high-voltage parts for traveling-wave amplifiers in ground stations or satellites, where the smoothing or filtering outlay must be minimized. In these cases, the detected load current is, in particular, the collector current of the traveling-wave tube, which is transformed into the low-voltage side of the switching controller using measuring current transformer SW.

Depending on the type of switching controller and the disturbing influences, e.g. input voltage fluctuations, etc., the signals at the second input of the pulsewidth/frequency modulator that are needed for optimal controller stability are different.

In the switching controller represented in Figure 3 of European Patent No. 0 355 333 [B1], these are:

-- a saw-tooth signal Q_{SK} of constant amplitude;
-- a signal RMI_L that is proportional to the current that is conducted through final controlling element S1; and
-- a saw-tooth signal Q_{SV}, whose peak amplitude is selected in proportion to the integrated input voltage of the switching controller.

In the [exemplifying] example embodiment [represented] shown in Figure 2 of EP 0 355 333 [B1], a d.c. voltage signal U_W is also included, which is selected in proportion to the level of the input voltage of the switching controller.

According to the present invention, it is possible to obtain a signal that is dependent upon the step change in load using a quantity other than the load current, for instance by detecting voltage jumps in the power circuit of the switching controller. These quantities can be suitably processed and fed as precontrol signals to the pulse-duration modulator or frequency modulator.

In the [exemplifying] example embodiment represented in Figure 3 of the present invention, the alternating component of the collector current of a traveling-wave amplifier is detected. The switching controller is used here as precontroller for a push-pull transformer GW. A high-voltage transformer HT that delivers the supply voltages for traveling-wave tube WF via high-voltage rectifier circuit HG is located in the output circuit of push-pull transformer GW. The primary winding of measuring current transformer SW1 of evaluation circuit A for evaluating collector current IC is located in the collector feed line to collector K of traveling-wave tube WF. The secondary coil is connected as [represented] shown in Figure 2. The output of evaluation circuit A leads via resistor RF1 to coupling device E, as [represented] shown in Figure 1. In traveling-wave tubes having two collectors, it usually suffices to evaluate one collector current as [represented] shown in Figure 3,

particularly the current of the collector that is situated in the immediate vicinity of the Wehnelt cylinder.

Abstract of the Disclosure

In a switching controller whose error signal amplifier [(KO)] essentially exhibits P action, the load step performance of the switching controller is detected via an evaluation circuit[(A)]. This signal is fed directly to the pulse- duration or pulse-frequency modulator [(PBM)] for the final controlling element[(S1)], substantially circumventing the error signal amplifier [(KO)] for the switching controller. [ ]Through this measure, output capacities of the switching controller can be reduced without stability problems.[

Figure 1]

13 Rec'd PCT/PTO 22 MAR 2001
09/623342

SWITCHING CONTROLLER

Background of the Invention

The present invention relates to a switching controller in whose control loop an error signal amplifier is provided, which essentially exhibits P (proportional) action and which acts on a pulse duration modulator or frequency modulator for the final controlling element of the switching controller. This type of switching controller is known from European Patent 0 355 333 B1.

In the switching controller described in European Patent 0 355 333 B1, noise signals on the input voltage are optimally suppressed in their effect on the output voltage of the switching controller without the control rate being adversely affected, for instance given sudden load variations. In order to prevent large voltage dips given sudden load variations at the output, for instance in the TDMA operation of a traveling-wave amplifier in a satellite, the voltage control loop must be properly dimensionally designed (high P component in the error signal amplifier). This can only be done when accompanied by a large enough output capacity, if the aim is for no stability problems to occur.

Advantages of the Present Invention

By applying the measures in accordance with the features of Claim 1, it is possible to dimensionally design the control loop to have a low P component. The output capacities of the switching controller can be reduced without causing control stability problems. This leads to a smaller type of construction for switching controllers in high-voltage parts, where substantial outlay is required for smoothing

capacitors.

The present invention is based on the realization that, through a so-called forward (uni-directional) control, the control loop can be dimensionally designed to have a low P-component; i.e., essentially circumventing the error signal amplifier, the step change in load is directly detected and delivered to the pulse-duration or pulse-frequency modulator, without the actual control loop having to respond. As a result of this precontrol, fewer automatic control delays follow step changes in load, without giving rise to stability problems.

When only the alternating component of the load current is detected for the precontrol, the precontrol decays with a time constant that can be selected such that the error signal amplifier can easily compensate for the decaying precontrol.

Drawings

Exemplifying embodiments of the present invention are elucidated detailed with reference to the drawing, whose figures show:

Figure 1: a basic circuit diagram of a switching controller in accordance with the present invention;
Figure 2: an evaluator for detecting a step change in load;
Figure 3: the detection of the collector current of a traveling-wave amplifier.

Description of Exemplary Embodiments

The switching controller illustrated in Figure 1 is designed as a buck (step-down) controller. It has an input d.c. voltage source Q_E, including a terminal voltage U_E. Disposed between the positive pole of the input d.c. voltage source

Q_E and the positive pole of the switching controller output having output voltage U_A is the series circuit of the switching controller's final controlling element S1 in the form of a switching transistor and inductor L of the switching controller. The freewheeling diode of the switching controller is denoted by DF, and the output-side smoothing capacitor by CG. Output voltage U_A is fed to an error signal amplifier KO, which compares it to a reference voltage Url. If output voltage U_A exceeds reference d.c. voltage Url, a control signal is transmitted to pulse-duration modulator PBM (non-inverting input), whose output signal determines the pulse duty factor (ON duration relative to OFF duration) of final controlling element S1. Connected to the inverting input of pulsewidth modulator PBM and of the common ground, is the series circuit composed of a resistor R1 and two signal sources Q_{SV}, Q_{SK}, which supply saw-tooth signals U_{SV} and U_{SK}. A voltage that is proportional to the input current of the switching controller drops across resistor R1. This is achieved in that resistor R1 is traversed by the flow of the rectified secondary current of a current transformer SMW, whose primary winding is located at the input circuit of the switching controller between input d.c. voltage source Q_E and final controlling element S1. The signal source Q_{SK} carries a saw-tooth voltage:

$$U_{SK(t)} = \hat{U}_{SK}\ t/T$$

t indicating the time, T the period duration of the saw-tooth repetition frequency, and $\hat{U}_{SK}$ the maximum amplitude of the saw-tooth voltage. The maximum amplitude $\hat{U}_{SK}$ of the saw-tooth voltage is kept constant. RM designates the resistance value of resistor R1 for detecting the current through the final controlling element; i.e., in the case of current detection by a current transformer as in Figure 1, the resistance value multiplied by the reciprocal [inverse] value of the transformation ratio of current transformer

SMW. Then, $RM = \frac{R1}{ü1}$ applies, ü designating the transformation ratio of current transformer SMW. Thus, to be able to maintain the stability conditions, a certain minimum saw-tooth amplitude is required, which cannot be provided solely by the control as a function of output voltage U_A. One can modify the action of the current control amplitude by modulating the saw-tooth amplitude by way of the input voltage. For this, an additional signal source Q_{SV} is provided, which carries a saw-tooth voltage

$$U_{sv(t)} = \frac{1}{RC} \int_0^1 U_{E(t)} dt$$

Thus, this saw-tooth voltage $U_{SV}(t)$ is proportional to integrated input voltage $U_E(t)$. The time dependency of input voltage U_E of the switching controller is substantially the result of superimposed alternating components, such as a 100 Hz ripple voltage in the case of a switched-mode power supply. This noise is optimally suppressed when the arithmetic mean of current I_0 through inductor L is constant. To optimally suppress fluctuations in input voltage and satisfy the stability requirement, the conditions discussed in detail in European Patent 0 355 333 B1 must be met.

At this point, the present invention provides for the load step performance of the switching controller to be detected, in particular, the alternating component of load current I_L, to be suitably amplified, and fed via a coupling device E between error signal amplifier KO, essentially exhibiting P action, to pulse-duration modulator PBM, via an evaluation circuit A, which, in the present exemplifying embodiment, is arranged between output-side smoothing capacitor CG and an output terminal of the switching controller. The supplying of the load-step-dependent signal directly to the input of pulsewidth modulator PBM does not alter the stability of the

controller, particularly with respect to phase margin and gain margin. As shown in Figure 1, coupling device E can be composed of a simple adding node or of an adding circuit, where the output signal from error signal amplifier KO is gated with the signal detected by evaluation circuit A. The two gated signals are preferably fed to the adding node via resistors RF1 and RF2 of equal value.

As Figure 2 shows, the alternating component of load current I_L is expediently detected by evaluation circuit A via a measuring current transformer SW and an amplifier V that is connected in series therewith. If there is no change in the load current, i.e., no change in current I_L (e.g. given a step change in load), then there is no signal at resistor RF1. As is evident from Figure 1, given resistors RF1 and RF2 of equal value, the output signal from error signal amplifier KO is effectuated at pulse duration modulator PBM with the half-amplitude ½ U_{KO}. If the controller gain is now increased by a factor of two, it can be seen that the additional precontrol does not influence the normal control loop via the signal that is detected by the evaluation circuit A; i.e., the controller stability is not changed. If the load then changes, namely if there is a modulation of the load current, then pulse duration modulator PBM is appropriately precontrolled without the actual control loop having to respond.

Since preferably only the alternating component of load current I_L is detected, the precontrol decays with time constant TAU = LH/RS, LH representing the primary inductance of measuring current transformer SW, and RS representing the cross resistance shown in Figure 2. Specifically, a great enough time constant TAU is selected to allow error signal amplifier KO to easily compensate for the decaying controller deviation of the precontrol.

Instead of a pulse duration modulator, a pulse frequency

modulator can also be provided for the switching controller. Furthermore, the present invention can be used for any type of switching controller, such as an step-up controller, a flow transducer, an isolating transformer, etc. The present. invention is particularly suitable for high-voltage parts for traveling-wave amplifiers in ground stations or satellites, where the smoothing or filtering outlay must be minimized. In these cases, the detected load current is, in particular, the collector current of the traveling-wave tube, which is transformed into the low-voltage side of the switching controller using measuring current transformer SW.

Depending on the type of switching controller and the disturbing influences, e.g. input voltage fluctuations, etc., the signals at the second input of the pulsewidth/frequency modulator that are needed for optimal controller stability are different.

In the switching controller represented in Figure 3 of European Patent 0 355 333 B1, these are:
-- a saw-tooth signal Q_{SK} of constant amplitude;
-- a signal RMI_L that is proportional to the current that is conducted through final controlling element S1;
-- a saw-tooth signal Q_{SV}, whose peak amplitude is selected in proportion to the integrated input voltage of the switching controller.

In the exemplifying embodiment represented in Figure 2 of EP 0 355 333 B1, a d.c. voltage signal U_W is also included, which is selected in proportion to the level of the input voltage of the switching controller.

According to the present invention, it is possible to obtain a signal that is dependent upon the step change in load using a quantity other than the load current, for instance by detecting voltage jumps in the power circuit of the switching controller. These quantities can be suitably

processed and fed as precontrol signals to the pulse-duration modulator or frequency modulator.

In the exemplifying embodiment represented in Figure 3 of the present invention, the alternating component of the collector current of a traveling-wave amplifier is detected. The switching controller is used here as precontroller for a push-pull transformer GW. A high-voltage transformer HT that delivers the supply voltages for traveling-wave tube WF via high-voltage rectifier circuit HG is located in the output circuit of push-pull transformer GW. The primary winding of measuring current transformer SW1 of evaluation circuit A for evaluating collector current IC is located in the collector feed line to collector K of traveling-wave tube WF. The secondary coil is connected as represented in Figure 2. The output of evaluation circuit A leads via resistor RF1 to coupling device E, as represented in Figure 1. In traveling-wave tubes having two collectors, it usually suffices to evaluate one collector current as represented in Figure 3, particularly the current of the collector that is situated in the immediate vicinity of the Wehnelt cylinder.

Patent Claims

1. A switching controller in whose control loop an error signal amplifier (KO) is provided, which essentially exhibits P action and which acts on a pulse-duration modulator or pulse-frequency modulator (PBM) for the final controlling element (S1) of the switching controller, comprising the following features:
-- an evaluation circuit (A) is provided for detecting the load performance of the switching controller;
-- a coupling device (E) for the signal that is detected by the evaluation circuit (A) is provided between the error signal amplifier (KO) and the pulse-duration or pulse-frequency modulator (PBM).

2. The switching controller as recited in Claim 1, characterized in that
the coupling device (E) at the input of the pulse-duration or pulse-frequency modulator (PBM) is composed of an adding circuit or an adding node, where the output signal from the error signal amplifier (KO) is gated with the signal detected by the evaluation circuit (A).

3. The switching controller as recited in Claim 1 or 2, characterized in that
the amplitude of the output signal from the error signal amplifier (KO), i.e., the gain of the error signal amplifier, is modified in comparison with a switching controller without a coupling device to a degree corresponding to the load-step-dependent quantity detected by the evaluation circuit (A).

4. The switching controller as recited in one of Claims 1 through 3,
characterized in that
the signal detected by the evaluation circuit (A) is the alternating component of the load current (IL) of the switching controller.

5. The switching controller as recited in one of Claims 2 through 4,
characterized in that
the signals that are fed to the adding circuit (E), i.e., to the adding node, are routed via resistors (RF1, RF2) of equal value.

6. The switching controller as recited in one of Claims 1 through 5,
characterized in that
the signal detected by the evaluation circuit (A) is provided as a precontrol signal for the pulse-duration or pulse-frequency modulator (PBM), the time constant of the evaluation circuit (A) being selected such that the error signal amplifier (KO) can compensate for the decaying control deviation caused by the precontrol signal.

7. The switching controller as recited in one of Claims 1 through 6,
characterized in that
the evaluation circuit (A) is composed of a measuring current transformer (SW) having a downstream amplifier (V).

8. The switching controller as recited in one of Claims 1 through 7,
characterized in that
the pulse-duration or pulse-frequency modulator (PBM) is fed the output signal from the error amplifier (KO) together with the superimposed output signal of the evaluation circuit (A), on the one hand, and the combination of at least two of the following signals, on the other hand:
-- a saw-tooth signal (Q_{SK}) of constant amplitude,
-- a signal ($RM \cdot I_L$) that is proportional to the current through the final controlling element (S1),
-- a saw-tooth signal (Q_{SV}) whose peak amplitude is selected in proportion to the integrated input voltage of the switching controller,
-- a d.c. voltage signal (U_W) which is selected in proportion to the level of the input voltage of the switching controller.

9. The switching controller as recited in one of the Claims 1 through 8,
characterized in that
the collector current (IC) of a traveling-wave tube (WF) is detected via the evaluation circuit (A).

Abstract

In a switching controller whose error signal amplifier (KO) essentially exhibits P action, the load step performance of the switching controller is detected via an evaluation circuit (A). This signal is fed directly to the pulse-duration or pulse-frequency modulator (PBM) for the final controlling element (S1), substantially circumventing the error signal amplifier (KO) for the switching controller.

Through this measure, output capacities of the switching controller can be reduced without stability problems.

Figure 1

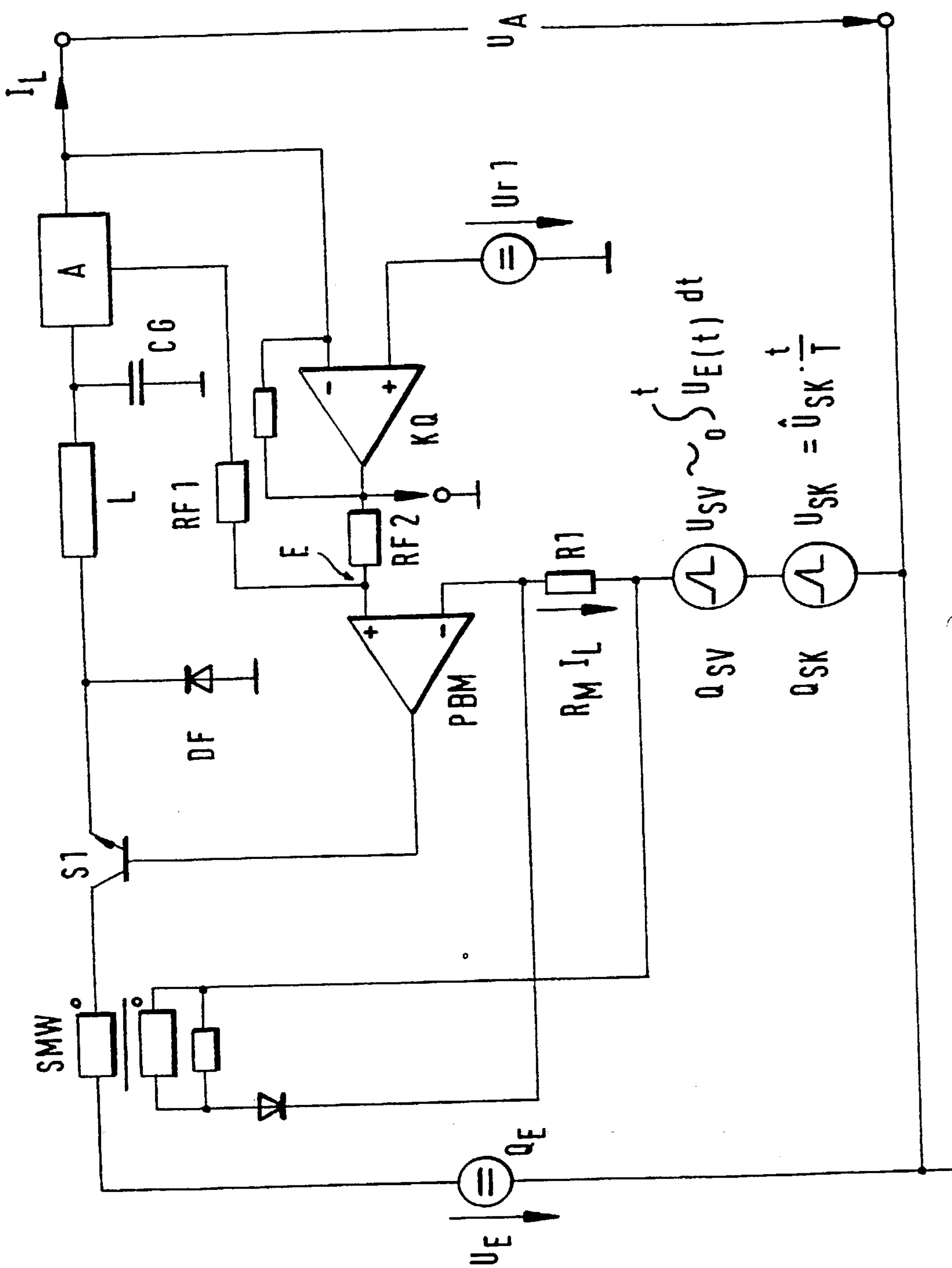
I_L
U_A
A
CG
L
RF 1
RF 2
E
KQ
Ur 1
PBM
DF
S1
SMW
Q_E
U_E
R1
R_M I_L
U_SV ~ ∫_0^t U_E(t) dt
U_SK = Û_SK · t/T
Q_SV
Q_SK

Fig. 1

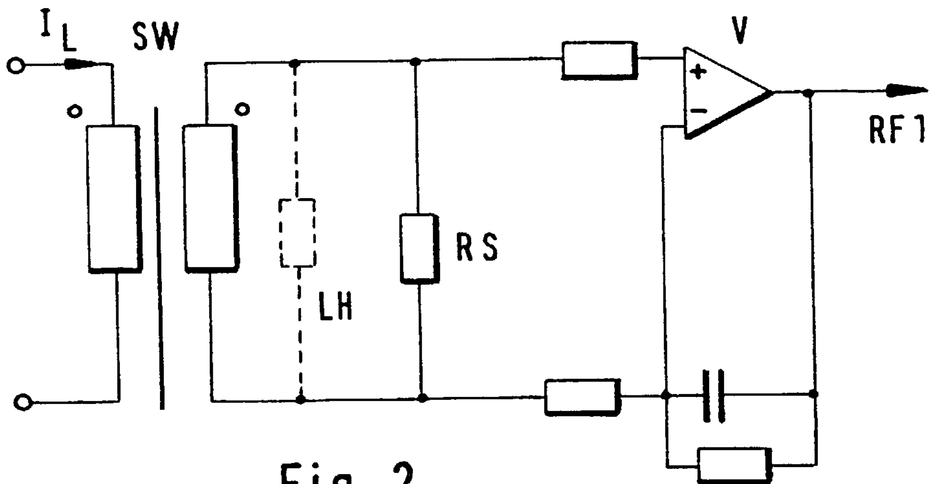

Fig. 2

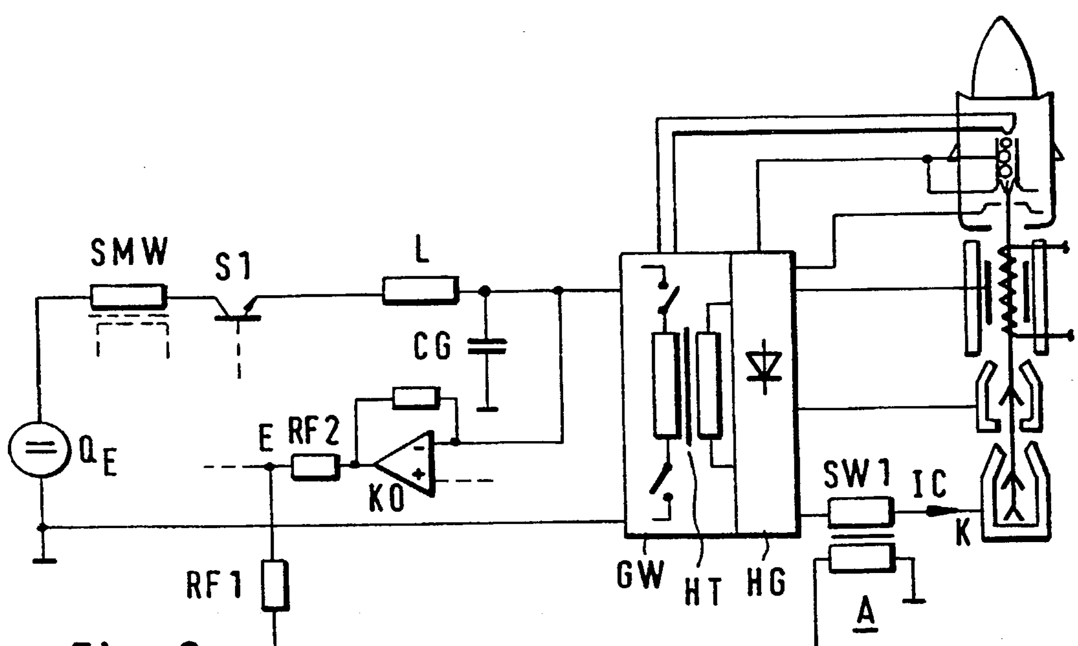

Fig. 3

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **SWITCHING CONTROLLER**, the specification of which was filed as PCT International Application No. **PCT/DE98/03741 on December 21, 1998**, now U.S. Serial No. 09/623,342.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country	Day/month/year filed	Priority Claimed Under 35 USC §119
198 09 385.3	Fed. Rep. of Germany	05 March 1998	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490), Gerard A. Messina (Reg. No. 35,952) and Michelle M. Carniaux (Reg. No. 36,098) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

3 -

Please address all communications regarding this application to:

KENYON & KENYON
One Broadway
New York, New York 10004

Please direct all telephone calls to Richard L. Mayer at (212) 425-7200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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Signature Gabriele Ohms Date 30. Oktober 2002

Gabriele Ohms

(Print Or Type Name)

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[ ] Administrator(trix) To The Estate Of Franz OHMS (Deceased.

[ ] Executor(trix) To The Estate Of Franz OHMS (Deceased).

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